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**UNITED STATES DISTRICT COURT  
 CENTRAL DISTRICT OF CALIFORNIA**

KEITH ANDREWS, an individual,  
 TIFFANI ANDREWS, an individual,  
 BACIU FAMILY LLC, a California  
 limited liability company, ROBERT  
 BOYDSTON, an individual, CAPTAIN  
 JACK'S SANTA BARBARA TOURS,  
 LLC, a California limited liability  
 company, MORGAN CASTAGNOLA, an  
 individual, THE EAGLE FLEET, LLC, a  
 California limited liability company,  
 ZACHARY FRAZIER, an individual,  
 MIKE GANDALL, an individual,  
 ALEXANDRA B. GEREMIA, as Trustee  
 for the Alexandra Geremia Family Trust  
 dated 8/5/1998, JIM GUELKER, an  
 individual, JACQUES HABRA, an  
 individual, ISURF, LLC, a California  
 limited liability company, MARK

**Case No. 2:15-cv-04113-PSG-JEM**

[Consolidated with Case Nos. 2:15-  
 CV- 04573 PSG (JEMx), 2:15-CV-  
 4759 PSG (JEMx), 2:15-CV-4989  
 PSG (JEMx), 2:15-CV-05118 PSG  
 (JEMx), 2:15-CV- 07051- PSG  
 (JEMx)]

**DECLARATION OF IGOR  
 MEZIC, PH.D., IN SUPPORT  
 OF PLAINTIFFS' MOTION  
 FOR CLASS CERTIFICATION**

Date: November 7, 2016  
 Time: 1:30 p.m.  
 Courtroom: Hon. Philip S. Gutierrez

1 KIRKHART, an individual, MARY  
2 KIRKHART, an individual, RICHARD  
3 LILYGREN, an individual, HWA HONG  
4 MUH, an individual, OCEAN ANGEL IV,  
5 LLC, a California limited liability  
6 company, PACIFIC RIM FISHERIES,  
7 INC., a California corporation, SARAH  
8 RATHBONE, an individual,  
9 COMMUNITY SEAFOOD LLC, a  
10 California limited liability company,  
11 SANTA BARBARA UNI, INC., a  
12 California corporation, SOUTHERN CAL  
13 SEAFOOD, INC., a California  
14 corporation, TRACTIDE MARINE  
15 CORP., a California corporation, WEI  
16 INTERNATIONAL TRADING INC., a  
17 California corporation and STEPHEN  
18 WILSON, an individual, individually and  
19 on behalf of others similarly situated,

20  
21 Plaintiffs,

22 v.

23 PLAINS ALL AMERICAN PIPELINE,  
24 L.P., a Delaware limited partnership,  
25 PLAINS PIPELINE, L.P., a Texas limited  
26 partnership, and JOHN DOES 1 through  
27 10,

28 Defendants.

**DECLARATION OF IGOR MEZIĆ, PHD.**

I, Igor Mezić, PhD, declare as follows:

1. I am a co-founder and Chief Technology Advisor of AIMdyn, Inc. I am also a Professor at the University of California, Santa Barbara and a Fellow of the American Physical Society, the premier organization of researchers in physical sciences. My research focuses on identifying key physical phenomena in a complex device or a natural system, and using that information to create forecasts or design new concepts on which devices can be built or improved.

2. For example, complex natural phenomena such as dispersion of oil on and below the ocean surface involve a large set of physical phenomena. Nonetheless, accurate predictions of where oil will flow can be made by identifying the key indicators (phenomena) that impact the flow and then computing where they will direct the flow. Such indicators and associated algorithms exist for a number of complex physical processes that involve mixing, including oil spills, jet engine instabilities and building energy efficiency indicators. As a result of my work in this area of research, the American Physical Society elected me as a fellow for my “fundamental contributions to the theory of three-dimensional chaotic advection, measures and control of mixing, and development of a spectral operator theory approach to decomposition of complex fluid flows.”

**ASSIGNMENT**

3. Plaintiffs in this action retained my services to develop an analysis to determine, to a reasonable degree of scientific certainty, where the oil from the Line 901 spill flowed in the ocean, including: (1) what geographic area it covered; (2) where it became submerged (including in kelp beds and crevices); (3) where it washed ashore; and (4) the extent to which submerged oil has reemerged onto the surface areas of the ocean.

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4. In this declaration, I explain how I can develop such an analysis, provide background on how oil “moves” in oceans, and present the results of my preliminary analysis.

5. I am being paid \$350/hour for my work on this assignment.

### **PROFESSIONAL BACKGROUND**

6. My research and teaching over the past twenty-eight years intersect the fields of fluid mechanics and mathematics. My undergraduate degree is in Mechanical Engineering, with emphasis on Thermal and Fluids Engineering. I received a Doctor of Philosophy (Ph.D.) from the California Institute of Technology (“Caltech”), within the Applied Mechanics Program, based on my Thesis entitled “On Geometrical and Statistical Properties of Dynamical Systems: Theory and Applications.” In my thesis, among other contributions, I developed a methodology to study kinematics of three-dimensional fluid flows, and published it in the paper Mezić, I., and Stephen Wiggins. "On the integrability and perturbation of three-dimensional fluid flows with symmetry." *Journal of Nonlinear Science* 4 .1 (1994): 157-194. This led to a series of research papers on three-dimensional motion of fluid particles and fluid mixtures, such as dye-water mixtures. I was credited with the development of this theory when I was inducted into the Fellowship of the American Physical Society, and will base my analysis of three-dimensional effects of Line 901 spill on it.

7. I was a postdoctoral fellow at the Mathematics Institute of the University of Warwick in the United Kingdom in 1994-1995. Beginning in 1995, I was an Assistant Professor at the University of California, Santa Barbara (“UCSB”) and I started a Nonlinear Dynamics research group at UCSB in 1995.

8. From 2000-2001, I was an Associate Professor at Harvard University. During that time I researched and then published one of the most cited papers on mixing in the history of the subject, in the prestigious journal *Science*. (Stroock, A. D., Dertinger, S. K., Ajdari, A., Mezić, I., Stone, H. A., & Whitesides, G. M.,

1 “Chaotic Mixer For Microchannels,” *Science* 295, 647-651 (2002).) This paper was  
2 subject to strict peer review prior to publication, and involved a number of the  
3 issues related to my analysis in this case.

4 9. I returned to UCSB and became a Full Professor there in 2003. In  
5 2006, I co-founded the Institute for Energy Efficiency at UCSB, where I still serve  
6 as the Head of Buildings and Design Group and Director of the Center for Energy  
7 Efficient Design.

8 10. I have received awards in three different scientific disciplines:  
9 automatic control; mathematics and dynamical systems theory; and technology  
10 development based on basic science. Among other awards, I was the recipient of  
11 the prestigious Sloan Fellowship in Mathematics in 1999. For my work on  
12 technology related to jet engines produced by Pratt and Whitney, I was awarded the  
13 United Technologies Senior Vice President's Special Award in 2007. My research  
14 and work involved a combination of fluid flow processes of complexity similar to  
15 the problem that is considered here. I was inducted to be the Fellow of the  
16 American Physical Society in 2016. I also have given a number of Plenary and  
17 Keynote lectures at conferences in Asia, Europe and the Americas on subjects  
18 similar to those discussed in this declaration.

19 11. I am a co-Founder of three companies that produce software and  
20 hardware related to flow processes: Aimdyn, iFluidics and Ecorithm. Aimdyn, Inc.  
21 was established in 2003 to develop powerful forecasting technologies for broad use  
22 in industry. Amongst its customers and collaborators are large corporations such as  
23 United Technologies, Ford and Cummins; researchers at prominent universities  
24 such as Princeton University; as well as preeminent national research agencies such  
25 as DARPA (Defense Advanced Research Project Agency) and NIH (the National  
26 Institutes of Health). Aimdyn has developed a suite of software tools that enable  
27 users to forecast and propose best remedial or control action for engineered or  
28 natural systems. Aimdyn has a depth of expertise in flow mechanics, mechanical

1 engineering, automatic control, vehicle terrain or ocean coverage and cleanup  
2 strategies and has developed proprietary software in each of these fields.

3 12. Many of the methods applicable to my analysis of where the oil flowed  
4 after entering the ocean relate to the topics described above, which I have been  
5 researching and applying for the past 28 years.

6 13. I have not provided expert testimony in any case in the last four years.

7 14. A copy of my CV is attached as Exhibit A.

8 **PREDICTING THE FLOW OF OIL IN THE OCEAN**

9 15. As noted above, years prior to the Deepwater Horizon oil spill, I  
10 developed an algorithm that I believed could be used to more accurately predict  
11 where the oil would flow in situations like that which ended up occurring in the  
12 Deepwater Horizon spill. That algorithm had been presented – to positive reviews –  
13 in lectures at the California Institute of Technology and the École Normale  
14 Supérieure in Paris.

15 16. After the Deepwater Horizon oil spill, and based on information  
16 available during that oil spill, I ran calculations through my algorithm and plotted  
17 where the oil would likely flow. Satellite observations of the oil slick confirmed the  
18 accuracy of my analysis. A comparison of the results of my analysis to satellite  
19 imagery are set forth in Exhibit B.

20 17. The type of modeling that led to accurate prediction of oil distribution  
21 during the Deepwater Horizon oil spill has been subjected to a high degree of  
22 scrutiny. The analysis and modeling underwent strict peer review and then was  
23 published in the journal *Science* in 2010. (Mezić, Igor, et al., "A New Mixing  
24 Diagnostic and Gulf Oil Spill Movement," *Science* 330, 486-489 (2010).) The  
25 publication of the analysis in *Science* attracted the attention of the scientific  
26 community. According to Google Scholar, the work has been cited more than 100  
27 times since its publication.

28



1           18. The analysis was expanded by looking at the behavior of the  
2 microbiological populations in the Gulf and their behavior during and after the  
3 Deepwater Horizon oil spill. The expanded work was invited for publication, and  
4 then published, in the Proceedings of the National Academies of Sciences by the  
5 then Administrator of NOAA and Under Secretary of Commerce for Oceans and  
6 Atmosphere, Dr. Jane Lubchenco. (Valentine, D., Mezić, I., Macesic, S., et al.,  
7 "Dynamic Autoinoculation and the Microbial Ecology of a Deep Water  
8 Hydrocarbon Irruption," *Proceedings of the National Academy of Sciences* 109,  
9 20286-20291 (2012).) This article also was subject to rigorous peer review. The  
10 article concluded that the analysis – performed using an ocean model – accounted  
11 for 80-90% of observed data within a kilometer range.

12           19. The analysis has been tested, subjected to peer review, published and  
13 is generally accepted in the scientific community. The analysis predicts, to  
14 reasonable degree of scientific certainty, the pathways of oil flowing from a spill  
15 site. The location of predicted pathways can be compared with the location of the  
16 observations from overflight data, satellite data, microbiological tests and shoreline  
17 samples, when such observations exist. Strict standards for processing of data are  
18 utilized when applying the methodology, the most important ones being the time  
19 and space resolution standards. The acceptance of the methodology in the scientific  
20 community is broad, with hundreds of papers citing its relevance for prediction of  
21 properties of mixing processes and oil spills.

22           20. A key component of this model is that it is able to derive the key flow  
23 structures in the ocean that impact the distribution of oil during and after a spill.  
24 These structures are not uniform in space, and produce what is known as an  
25 “effective diffusivity” that depends on non-uniform flow structures. This, in turn, is  
26 referred to as the spatial dependence of effective diffusivity.

27           21. By way of example, and speaking in simplified terms, ocean flows  
28 have three primary types of structures that can carry oil. Each impacts oil

1 differently. (1) Eddies are rotational, relatively slow mixing zones. Oil will either  
2 not enter these zones or will enter them slowly and then rotate within the confined  
3 area of the eddy until the eddy, or a portion of the eddy, becomes a different  
4 structure. (2) Shear regions move linearly in one spatial direction at a time and can  
5 change direction multiple times over the course of the day. Oil readily enters these  
6 regions, is stretched, and generally moves in the direction the shear region is  
7 moving. When the shear region's direction changes back and forth, the oil  
8 effectively sloshes back and forth. (3) Mixing zones are regions where rotational  
9 and shear motion is combined to produce a mixture over a surface area. In these  
10 zones, oil is repeatedly stretched and then folded back on itself, similar to how  
11 hand-pulled noodles are made.

12 22. Returning to the concept of the spatial dependence of effective  
13 diffusivity, the oil is pushed or pulled (effective diffusivity) differently based on  
14 where and when it encounters each structure (spatial dependence).

15 23. Eddies, shear regions, and mixing zones can be identified based on  
16 velocity – the rate at which positions in the ocean change. Information on velocity  
17 is readily available, either through actual data from high frequency radar  
18 measurements or through computed data.

19 24. The approach to calculating distinguished structures that are  
20 responsible for dispersion in ocean flows relies on following oil-carrying fluid  
21 volume tracks over a finite period of time corresponding to the period over which a  
22 prediction is required. For this, the velocity field  $v$  of the ocean is needed as an  
23 input. This is supplied either by a numerical model (as was the case during the  
24 Deepwater Horizon oil spill) or measured velocities (as was the case during the  
25 Refugio oil spill).

26 25. Once you have the velocity field, you compute its average over  
27 particle tracks over a finite period, and call it  $v^*$ , the average Lagrangian velocity.  
28



1 This quantity depends on the initial position of the oil particles and the time period  
2 over which it is computed.

3 26. The crucial step comes next: You compute the difference in average  
4 Lagrangian velocities that nearby oil particles experience. That difference is labeled  
5  $\nabla v^*$ . This is a matrix that depends on initial conditions and the time-period  $T$ . You  
6 then categorize the different regions by the values of the determinant of that matrix,  
7  $\det \nabla v^*$ . The negative values of this quantity correspond to rotation with strain of  
8 nearby particles, and are presented graphically in red. The positive values, less than  
9  $4/T^2$ , represent elliptic, quiescent regions and are labeled green or white. The  
10 positive values, larger than  $4/T^2$ , represent hyperbolic behavior and are shown in  
11 figures by blue color.

12 27. Streaks of red and blue next to each other can be interpreted as shear  
13 zones, where the distribution of oil gets stretched along in the direction of the  
14 streak. Green zones can be interpreted as the regions where the motion of the oil  
15 does not produce much deformation in the shape of its spatial distributions. Zones  
16 with intricate mixtures of red and blue can be interpreted as mixing areas where the  
17 oil is spread over a substantial portion of the affected field. These structures are  
18 jointly called hypergraph structures.

19 28. Once the distribution of these structures at different points in time are  
20 identified, other relevant data is incorporated to determine to a reasonable degree of  
21 scientific certainty where the oil is going to flow. For example, wind effects and  
22 evaporation effects can be included using appropriate modeling tools.

### 23 **APPLYING THIS ANALYSIS TO THE LINE 901 SPILL**

24 29. It is estimated that The Refugio oil spill ("Line 901 spill") – starting at  
25 the Refugio State Beach on May 19, 2015 – volume amounted to 142,800 U.S.  
26 gallons (3,400 barrels) of crude oil. The analysis described above is readily  
27 applicable to the Line 901 spill. Access to actual measured velocity data in  
28 connection with the Line 901 spill provides an even greater degree of certainty than

1 was possible with the computed data available in connection with the Deepwater  
2 Horizon spill. Further, because I am able to obtain daily velocity data and other  
3 relevant information, I am able to determine to a reasonable degree of scientific  
4 certainty what happened to the oil between the time of the Line 901 spill through  
5 the time I submit my expert report.

6 30. The analysis will take the following approach:

- 7 • Velocity data will be obtained from high frequency radar measurements.  
8 An example of the velocity field so obtained is shown in Ex. C. This  
9 will serve as the previously described velocity field  $v$ .
- 10 • The algorithm described above will then process the velocity data to  
11 determine the water structures in place at different times throughout the  
12 relevant geographic region. Specifically, we will compute  $\det \nabla v^*$  and  
13 determine the hypergraph structures described above according to the  
14 values of that field.
- 15 • The initial distribution of oil in near-shore region will be determined.  
16 Subsequent distribution of oil will be determined and compared with  
17 hypergraph structures. This will be performed using industry-accepted  
18 equations modeling near-shore behavior taking into account diffusion  
19 caused by winds and waves and also turbulence.
- 20 • Wind data will be incorporated into the analysis through industry-  
21 accepted methodologies and its effect on the distribution evaluated.
- 22 • Evaporation data will be incorporated into the analysis and its effect on  
23 the distribution evaluated. This is a basic formula that has broad  
24 industry acceptance.
- 25 • The analysis of near-shore and off-shore processes will allow me to  
26 determine where and when oil became submerged. 3-D modeling will be  
27 incorporated to address submerged oil. This will also indicate when and  
28

1 where oil re-emerged. As described above this is a type of analysis  
2 that I have significant experience performing.

- 3 • The actual path the oil travels through the ocean will be determined by  
4 combining the information from the hypergraphs with particle tracking  
5 methodologies, another analysis that has broad industry acceptance.  
6 Fitzpatrick, Faith A., et al. *Oil-particle interactions and submergence*  
7 *from crude oil spills in marine and freshwater environments: review of*  
8 *the science and future research needs*. No. 2015-1076. US Geological  
9 Survey, 2015.
- 10 • Clean-up data will be used to incorporate when, where, and how much  
11 oil was removed from the ocean.
- 12 • Uncertainty analysis will be performed using Aimdyn's software  
13 GoSUMd in order to confirm the robustness of results to uncertainties.

14 31. Using this approach, I am able to provide an hour-by-hour analysis,  
15 allowing me to determine to a reasonable degree of scientific certainty where (and  
16 when) the oil travelled, became submerged, including in kelp beds and crevices,  
17 and washed ashore, and the extent to which submerged oil has reappeared on the  
18 shoreline.

19 32. To further confirm the validity of the analysis, the results of the  
20 analysis will be compared to available data on where oil was actually identified.  
21 This will include the NOAA flyover data available from May 21 to May 31 (an  
22 example of which is attached as Ex. F), and data obtained by NOAA related to  
23 fingerprinting of oil located on shore.

24 **PRELIMINARY RESULTS OF THE ANALYSIS OF OIL FLOW IN THE**  
25 **OCEAN FROM LINE 901**

26 33. I have already performed a preliminary analysis of the pathways  
27 available for the oil to flow after the spill. This analysis considers the flow  
28 structures in the relevant area over the first 10 days following the spill. This is the

1 first step of my analysis and it provides a reliable picture of the area the oil  
2 covered. Indeed, as described below, actual oil sightings confirm the validity of  
3 this preliminary analysis.

4 34. Attached as Exhibit D is a 10-day hypergraph that provides a coarse  
5 analysis of the pathways of probable oil dispersion through the first ten days of the  
6 spill. This analysis shows that, to a reasonable degree of scientific certainty, the  
7 flow structures would transport the oil from the spill site at Refugio out to the  
8 Channel Islands, slightly up the coast, and down the coast past Laguna Beach. The  
9 use of particle tracking methodologies and other analyses (referenced above) in my  
10 final analysis will be able to confirm where the flow structures actually transported  
11 the oil.

12 35. Exhibit E is another 10-day hypergraph. This one applies a finer  
13 resolution computation and is focused on the area closest to Santa Barbara to show  
14 the detail that can be applied to the hypergraphs. Exhibit E shows the flow  
15 structures transporting the oil along the Santa Barbara coast and then causing the  
16 oil to disperse, heading south and to the Channel Islands. Again, the use of particle  
17 tracking methodologies in my final analysis will be able to confirm where the flow  
18 structures actually transported the oil.

19 36. Actual oil sightings during the time period covered by this preliminary  
20 analysis confirm the validity of the analysis. For example, NOAA performed  
21 flyovers along the Santa Barbara coast to identify oil in the ocean. The NOAA  
22 flyover from the 10th day after the spill is attached as Exhibit F. It shows oil in the  
23 locations where Exhibit E predicts oil will flow.

24 37. I also superimposed the NOAA flyover data from Exhibit F onto the  
25 Exhibit E hypergraph. The result is attached as Exhibit G. The empty circles in  
26 Exhibit G reflect the position of the airplane when oil was observed. Small brown  
27 circles show the hypergraph closest to the position of the plane. All distances are  
28 within 1 kilometer, which is within the resolution of the model.



**CERTIFICATE OF SERVICE**

I, Robert J. Nelson, hereby certify that on August 22, 2016, I electronically filed Plaintiffs' **DECLARATION OF IGOR MEZIĆ, PH.D., IN SUPPORT OF PLAINTIFFS' MOTION FOR CLASS CERTIFICATION** with the Clerk of the United States District Court for the Central District of California using the CM/ECF system, which shall send electronic notification to all counsel of record.

/s/ Robert J. Nelson  
Robert J. Nelson